# A Routing Metric Based on Available Bandwidth Routing in Wireless Mesh Networks

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**Abstract** – Wireless Mesh Network has drawn much attention due to wide area service coverage with low system cost and being easy to install. However, WMN suffers from high bit error rate, which provides different link capacity among wireless mesh routers. The conventional routing metrics select the path based on link quality. The link with the best quality is preferred as the data transmission path, and thus all nodes likely select the same link, which leads to network performance degradation. This paper proposes a routing metric that considers the available bandwidth and the number of nodes suffering congestion in the path. It is confirmed that the proposed method provides higher network performance of reduced delay, reduced packet loss and increased throughput than conventional routing metrics.

***Key words*** – *routing metric*; *overload aware*; *available bandwidth*; *multi-channel*; *wireless mesh network*

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## 1 Introduction

With the recent increase of mobile terminals, the number of wireless Internet users is steadily rising. The current Internet access service through Access Points (APs) requires installation of many APs due to their limited range. Increase of APs not only increases system deployment costs, but also cause problems of spatial occupation due to installation of wired network construction[1,2].

As shown in Fig. 1, a wireless mesh network is generally composed of wireless mesh clients, wireless mesh routers which act as AP and router, and wireless mesh gateways which connect to the Internet.

Various routing techniques have been extensively studied for effective traffic transmission in ad hoc networks[4-6]. These routing techniques can be largely divided into the proactive method that selects path to the destination by periodically refreshing and exchanging routing table based on the path selecting criteria for data transmission and the reactive method that selects a path each time for the traffic transmitting. Since a wireless mesh network maintains its topology once it is formed unless a new mesh router is installed or removed, the proactive method is more advantageous than the reactive method[7].

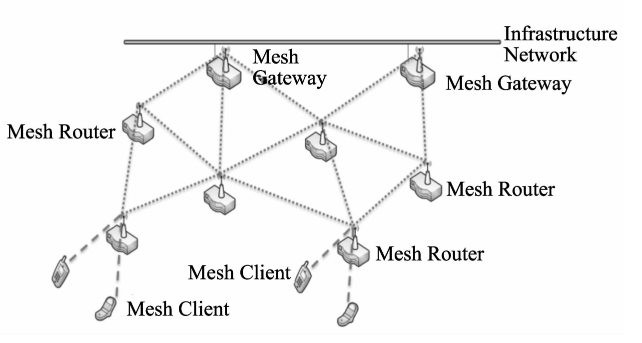


**Fig. 1** Wireless mesh networks architecture

Routing of the proactive method has generally used the routing metrics based on link quality for path selection. The conventional routing metrics based on link quality select the best route by measuring the quality between links considering bandwidth, error rate, packet size, and etc[8,9]. When the conventional routing metrics based on link quality is used, the link with the best quality is preferred as the data transmission path, and thus all nodes likely select the same link, which causes link congestion. Consequently, links of good quality become congested in traffic while the links with low quality are rarely used, which leads to network performance degradation.

In this paper, we propose a routing metric considering available bandwidth and the number of nodes suffering congestion in the path. The proposed routing metric improves network by proportionally distributing network traffic among mesh routers according to the available bandwidth.

This paper is organized as follows. Section 2 de-

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scribes the problems of conventional routing metrics. Section 3 represented the path selection method using the proposed routing metrics. And section 4 analyzes performance of the proposed routing metrics through simulation compared to the conventional metrics. Finally, section 5 concludes the paper.

## 2 Related works

The routing based on link quality determines the path using various criteria, and sends traffic through the path which has the best link quality. The conventional routing metrics based on link quality and their limitations are described below.

### 2.1 Hop Count

The Hop Count is a routing metric generally used in multi-hop wireless networks such as AODV (Ad hoc On-demand Distance Vector), DSR (Dynamic Source Routing) and DSDV (Destination-Sequenced Distance Vector). It uses the minimum hop count as the path selection criterion. This path selection method is very simple and effective if the network is highly stable. However, if the network is unstable, its performance quickly decreases.

### 2.2 Packet Pair and RTT

In Packet Pair method, transmission node sends two packets to the reception node, which measures the delay and sends it to the transmission node. RTT method also measures the delay by sending probe packets. The two methods have the problem that their network status is checked and reflected in routing at the limited sampling points.

### 2.3 Expected Transmission Count (ETX)

In ETX, a node broadcasts a fixed number of probe packets to neighbor nodes and measures error rate by identifying how many probe packets have successfully arrived. Eq. (1) shows how ETX measures error rate, where $d_f$ is the forward transmission rate and $d_r$ is the reverse transmission rate. A lower ETX indicates a better path. This approach has the problem that bidirectional error rates cannot indicate the bandwidth and traffic.

$$ETX = \frac{1}{d_f \times d_r}. \tag{1}$$

### 2.4 Expected Transmission Time (ETT)

ETT is a metric that has been improved from ETX by considering link bandwidth and packet size in the routing metric. ETT can improve the network performance compared to ETX. Eq. (2) shows how ETT is calculated, which is expressed as ETX multiplied by the average packet size, $S$, divided by the bandwidth $B$ of the current link. However, ETT did not take the link congestion into consideration, so the link suffering bottleneck experience rapidly decreases in performance. In addition, efficiency is low because the metric is calculated in each hop.

$$ETT = ETX \times \frac{S}{B}. \tag{2}$$

### 2.5 WCETT

WCETT (Weighted Cumulative Expected Transmission Time) is an improvement of ETT. It proposes a routing metric which considers the sum of ETT values on the path and reflects each channel environment in a multi-channel environment.

$$WCETT = (1-\beta) \times \sum_{i=1}^{n} ETT_i + \beta \times \max_{1 \leqslant j \leqslant k} X_j, \tag{3}$$

$$X_j = \sum_{hop\ i\ is\ in\ Channel\ j} ETT_i \quad (1 \leqslant j \leqslant k). \tag{4}$$

Eq. (3) shows the WCETT equation which consists of sum of ETT till $n$ hop-away destination and the expected transmission values of the multi-channels. Expected transmission value in the multi-channels is determined by the maximum in $X_j$ values for each channel. Eq. (4) shows that $X_j$ is the sum of ETTs that uses the same channel for a given path. WCETT inherits the shortcomings of ETT.

The conventional routing metrics only takes link quality in the routing process into consideration. Thus, the link of high quality is likely to be selected, which leads to congestion at those links as well as adjacent links.

## 3 Proposed algorithm

The proposed algorithm called eWCETT (enhanced-WCETT) overcomes shortcomings of conventional routing metrics by considering the available bandwidth and overload condition.

Enhanced-WCETT enhances WCETT by adding two factors: available bandwidth and load on the link. Enhanced-WCETT is the accumulated value of eETT (enhanced-ETT) for each path, and is expressed as Eq. (5). Multi-channels can be considered in WCETT, but only single channel is considered in this paper, which makes $\beta$ be zero.

$$eWCETT = (1-\beta) \times \sum_{i=1}^{n} eETT_i + \beta \times \max_{1 \leqslant j \leqslant k} X_j,$$

$$\text{if } \beta = 0,\ eWCETT = \sum_{i=1}^{n} eETT_i. \tag{5}$$

As shown in Eq. (6), eETT can either be conventional ETT or mETT (modified-ETT) depending on $\lambda$, where $\lambda$ can have binary value either 0 or 1. If overload condition presents, eETT is determined by mETT for performance enhancement. Otherwise, eETT is determined by conventional ETT. How to set $\lambda$ will be explained later in Eq.(8).

$$eETT = \lambda \times ETT + (1 - \lambda) \times mETT. \quad (6)$$

The metric mETT can be obtained by Eq.(7), where the conventional ETT is modified by adding a parameter available bandwidth $P$. The available bandwidth $P$ can be obtained by subtracting average incoming traffic $avg(T_t)$ at time $t$ from average bandwidth $avg(B_t)$ at time $t$, which indicates the average maximum achievable bandwidth over the given time interval, while $avg(T_t)$ indicates aggregate incoming traffic volume at the specific output link (queue).

$$mETT = ETX \times \frac{S}{P},\ P = avg(B_t) - avg(T_t). \quad (7)$$

Eq.(8) expresses the method for selecting either ETT or mETT depending on $\lambda$ . As explained earlier, if $\lambda = 1$, eETT can be calculated with conventional ETT. Otherwise eETT can be calculated from mETT.

Determination $\lambda$ is related to $QL_i$, which is shown in Eq.(8). $QL_i$ indicates the number of mesh routers suffering overload condition along the path, where each mesh router sets $Q_k$ to either zero for no overload condition or one for overload condition.

To determine $\lambda$, $QL_i$ is compared with the threshold. For example, when the threshold is set to 1 and $QL_i$ is less than 1, there is no wireless mesh router suffering overload along the path. In this case, it is better to use conventional ETT in routing metric calculation. If $QL_i$ is equal to or more than 1, there is at least one wireless mesh router suffering from overload. Then, it is better to use mETT in routing metric calculation.

The rationale of proposed routing metric is that when network is stable (no congestion), the conventional ETT is selected for routing metric because ETT selects the link which has the highest bandwidth to reduce packet loss and delay. However, when network is partially congested, the modified mETT is selected for routing metric because it is better to consider available (residual) bandwidth, which leads to distribution of network traffic to other parts with more residual bandwidth.

$$QL_i = \sum_{n=0}^{H_i} Q_k (1 \leqslant i \leqslant m),$$
$$\begin{cases} if,\ Threshold \leqslant QL_i,\ \lambda = 0; \\ else, \qquad \lambda = 1. \end{cases} \quad (8)$$

# 4 Simulation

To verify performance of the proposed eWCETT, a simulation environment based on C++ was constructed. The parameter values used for simulation are listed in Tab.1.

Tab.2 shows the cases of different traffic load patterns at specific nodes. The traffic load is defined as an amount of local traffic generated by the users in a single cell. Each user generates 1Kbyte packet in 40 ms and 1.0 fold of traffic load is defined when 10 users are generating packet in a single cell. It is assumed that all links have equal bandwidth of 54 Mbps.

**Tab.1** Simulation Parameters

| Parameter | Value |
|---|---|
| Topology | 10×10 Grid |
| Number of Nodes | 30 |
| Data Packet Size(byte) | 1 000 |
| Probe Packet Size(byte) | 500 |
| Traffic | UDP |
| MAC Protocol | CSMA/CA |
| Bandwidth(Mbps) | 54 |
| Simulation Period(sec) | 500 |
| Table Update Period(sec) | 5 |
| Threshold | 1 |

In case 1, there is no overload condition in network. In case 2, node A generates 1.5 fold of traffic load, and thus link from node A suffers overload. Other cases (case 3, case 4, case 5) suffers overload at the links that connect the node generating traffic load more than 1.0 fold. It is assumed that the conventional routing metric selects the path with link A due to its shortest path to the destination.

For the cases shown in Tab.2, the performance of two routing metrics (WCETT and eWCETT) is compared in terms of average packet delay, packet loss and average throughput.

**Tab.2** Cases of traffic generation patterns at each node

| | Node A | Node B |
|---|---|---|
| CASE 1 | 1 fold | 1 fold |
| CASE 2 | 1.5 fold | 1 fold |
| CASE 3 | 1.5 fold | 1.3 fold |
| CASE 4 | 2 fold | 1 fold |
| CASE 5 | 1.5 fold | 1.4 fold (Node B)<br>1.3 fold (Node C)<br>1.2 fold (Node D) |

Fig. 2 shows the average delays of WCETT and eWCETT. In case 1 where there was no overload, WCETT and eWCETT showed the same average delay. The reason is that when there is no overload, in both routing metrics, eETT is obtained from ETT.

For cases 2 to 5, the conventional routing metric would select the path with link A as mentioned earlier. Thus, the packet delay increases due to overload at the link that connects node A.

However, the proposed routing metric can select the other path without overload condition by using mETT, which is possible due to the use of available bandwidth. Thus eWCETT results in lower packet delays.

Fig. 3 and Fig. 4 show packet loss and throughput for cases 1 to 5. Similar to the average packet delay, eWCETT and WCETT showed the same performance in packet loss and throughput with no overload condition. However, when the overload condition presents, eWCETT distributes the traffic load to other path that are not overloaded. This results in lower packet loss and higher throughput than WCETT.

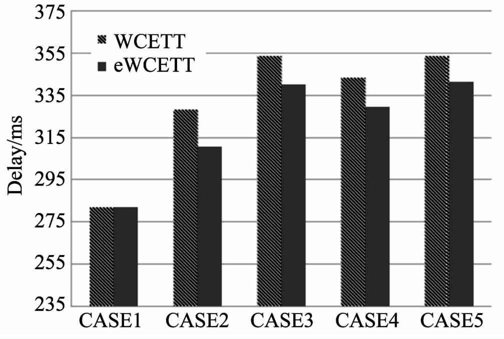


**Fig.** 2 Average delay

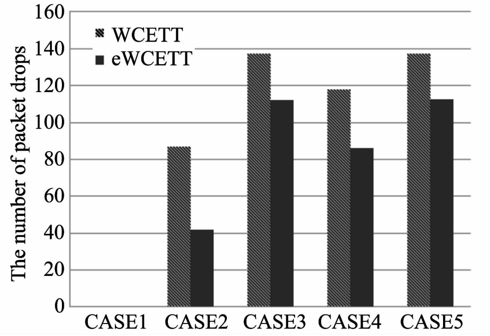


**Fig.** 3 Packet drops

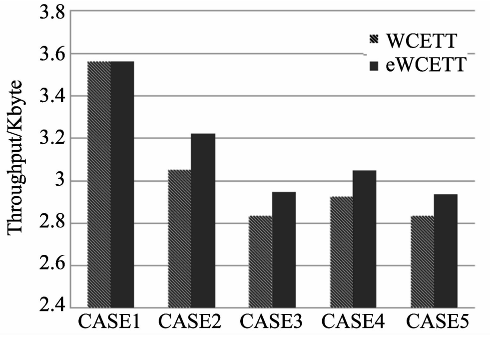


**Fig.** 4 Average throughput

## 5 Conclusions

Wireless Mesh Network has drawn much attention due to wide area service coverage with low system cost and being easy to install. However, WMN has such disadvantages as unstable channel characteristics, high error rate and limited bandwidth among wireless mesh routers. In order to solve these problems, various routing methods have been studied. However, the existing methods decreased the performance depending on network situation because they only considered channel state like bandwidth, packet size and error rate.

To overcome shortcomings of the conventional routing metrics, this paper proposed metrics looking for the best routing path by considering the available bandwidth and overload. Performance of the proposed method including low delay, high transmission rate and low packet loss is verified through simulations. It is confirmed that the proposed method provides higher performance than the conventional methods.

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